

Claims

[c1] What is claimed is:

1. A method of clinical imaging comprising:
exciting water-exchangeable spins in oxygen-bearing molecules in a region-of-interest (ROI) having a change in oxygen status;
detecting proton transfer within the ROI from exchangeable protons within water; and
determining changes in oxygen levels across the ROI.

[c2] 2. The method of claim 1 further comprising irradiating the ROI with exchangeable resonances and wherein the exchangeable resonances are within a resonance in a proton spectrum of one of deoxy-hemoglobin and dexoy-myoglobin.

[c3] 3. The method of claim 2 further comprising selectively irradiating the ROI and distinguishing water signal changes within the ROI due to deoxy-hemoglobin and or deoxy-myoglobin from background MT effects.

[c4] 4. The method of claim 3 wherein the proton spectrum is within at least one of a range of approximately -10 to 80 ppm.

- [c5] 5. The method of claim 1 wherein exciting includes irradiating the ROI such that spins of at least one of deoxy-hemoglobin and deoxy-myoglobin is excited.
- [c6] 6. The method of claim 1 further comprising assessing oxygen depletion within the ROI.
- [c7] 7. The method of claim 1 further comprising acquiring MR imaging data from the directly imageable molecules via proton transfer to enhance contrast between oxygen-rich and oxygen-depleted tissue in the ROI.
- [c8] 8. The method of claim 1 further comprising acquiring spectral data to perform a spectral analysis of oxygen content within the ROI.
- [c9] 9. The method of claim 1 further comprising mapping the oxygen levels across the ROI.
- [c10] 10. A method of determining oxygenation of heme-proteins in vivo comprising:
 - applying radio frequency (RF) energy to an imaging subject to excite off-resonance spins of water-exchangeable molecules;
 - determining proton transfer from excited water-exchangeable molecules to non-excited molecules;
 - acquiring MR data from the non-excited molecules; and

determining oxygen content of the water-exchangeable molecules from the MR data.

- [c11] 11. The method of claim 10 further comprising determining a concentration of at least one of deoxy-hemoglobin and deoxy-myoglobin in the imaging subject.
- [c12] 12. The method of claim 10 further comprising determining a spatial distribution of oxygen debt across a data acquisition region.
- [c13] 13. The method of claim 10 further comprising determining proton transfer from the water-exchangeable molecules to water molecules.
- [c14] 14. The method of claim 10 wherein applying RF energy further comprises applying off-resonance RF pulses.
- [c15] 15. The method of claim 10 wherein applying RF energy further comprises applying a paramagnetic hyperfine-shifted exchangeable resonance RF pulse sequence to the imaging subject.
- [c16] 16. A magnetic resonance imaging (MRI) apparatus comprising:
an MRI system having a plurality of gradient coils positioned about a bore of a magnet to impress a polarizing

magnetic field and an RF transceiver system and an RF switch controlled by a pulse module to transmit RF signals to an RF coil assembly to acquire MR images; and a computer programmed to:

cause application of a pulse sequence to excite oxygen-bearing molecules within a ROI having a change in oxygenation;

acquire MR data from directly imageable molecules having been influenced by the oxygen-bearing molecules; and

reconstruct an image from the MR data to illustrate a change in oxygen debt across the ROI.

[c17] 17. The MRI apparatus of claim 16 wherein the oxygen-bearing molecules include deoxy-heme-proteins.

[c18] 18. The MRI apparatus of claim 17 wherein the deoxy-heme-proteins include at least one of deoxy-hemoglobin and deoxy-myoglobin.

[c19] 19. The MRI apparatus of claim 16 wherein the oxygen-bearing molecules include proximal histidine NH.

[c20] 20. The MRI apparatus of claim 16 wherein the computer is further programmed to determine oxygen concentration across the ROI.

[c21] 21. The MRI apparatus of claim 16 wherein the computer

is further programmed to map oxygenation levels across the ROI.

[c22] 22. The MRI apparatus of claim 16 wherein the RF pulse sequence is configured to excite the oxygen-bearing molecules to a saturation such that a water transfer effect excites the directly imageable molecules.

[c23] 23. The apparatus of claim 16 wherein the computer is further programmed to cause the ROI to be irradiated with multiple exchangeable resonance frequencies to enhance resolution of the image.

[c24] 24. The apparatus of claim 16 wherein the computer is further programmed to cause the ROI to be irradiated with multiple exchangeable resonance frequencies substantially simultaneously.

[c25] 25. A system of oxygen content determination comprising:
means for exciting spins limited to targeted oxygen-carrier molecules;
means for determining a proton transfer from the targeted oxygen-carrier molecules to imageable molecules;
and
means for determining oxygenation of the targeted oxygen-carrier molecules from a reconstructed image of the

imageable molecules.

- [c26] 26. The system of claim 25 further comprising means for limiting spin excitation to proximal histidine NH molecules in an ROI.
- [c27] 27. The system of claim 25 further comprising means for displaying a spatial distribution of oxygen depletion across the ROI.
- [c28] 28. The system of claim 25 further comprising means for determining a concentration of at least one of deoxy-hemoglobin and deoxy-myoglobin in the ROI.
- [c29] 29. The system of claim 25 further comprising means for determining cancerous tissue presence in an ROI.
- [c30] 30. The system of claim 25 further comprising means for localizing oxygen depletion across an ROI.